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DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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THE SUN AND THE WEATHER*

BY C. G. ABBOT

"CHANGEABLE as the weather," we say, when the roaring gale follows hard on the heels of a cloudless day. But from another point of view the wonder is that weather changes disastrous to life occur so seldom. Experiments indicate that the higher forms of plants can not grow where temperatures remain continuously below 0° or above 50° C. (32° and 122° F.). These are extremes, and most food plants can only thrive within much narrower ranges. Wheat and maize are grown within the belt whose mean yearly temperature lies between 4° and 20° C., oats and barley − 2° to 20° C., rice 20° to 30° C., and potatoes 2° to 16° C.

Despite these limiting conditions, no migrations of men seem to have been forced by climatic changes within historical times, extending over 5,000 years, and there is no evidence to show that the habitats of food plants have altered their latitudes during this interval. Geological evidence, however, indi-

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cates that such changes and accompanying forced migrations have occurred in past ages, but probably not of great magnitude within intervals of 5,000 years.

To bring out more strongly this remarkable constancy, in a recent paper Sir F. Stupart says :—

> One of the arguments in favor of stability of climate, first used by the Danish botanist and meteorologist Schouw, is as follows: In order that dates shall come to maturity the mean annual temperature must be at least 69°F. (20·6° C.). On the other hand, the vine can not be profitably cultivated when the mean annual temperature exceeds 72° F. (22·2° C.) . . . . The palm and vine grew together in Palestine in the days of early biblical history, and they both grow in the same district to-day. . . . . That the rainfall of Palestine has not changed in 2,000 years receives confirmation from some measures of rainfall recorded in the Mishnah. . . . .

The temperature of the earth depends almost wholly on the balance of two energies. First is the incoming energy of the sun's rays, both visible and invisible, second is the outgoing energy of the earth's rays. These latter are wholly invisible to the eye, and can only be detected by thermometric appliances. The fundamental nature of earth rays, however, in no way differs from that of light. The only difference resides in their wave-lengths. Light-waves range from 0·0004 to 0·0008 millimeter, earth-ray waves from 0·004 to 0·050 millimeter. The hotter the earth's surface becomes, the more copiously it emits these long-wave rays, so that at a certain temperature of the earth its output of energy to space equals its income, which is almost wholly from the sun. Solar rays lie chiefly between 0·0003 and 0·003 millimeter in wave-length, although extending feebly to very long-wave regions.

Neither sun-rays nor earth-rays pass freely through the atmosphere. Clouds, dust, water-vapor, carbon-dioxide, oxygen, and even the molecules of the air — all hinder the passage of the solar rays. Approximately 40 per cent. are reflected away to space without tending in the least to sustain the terrestrial temperature. Of the remaining 60 per cent. about one fifth, or 12 per cent., is absorbed in the atmospheric water-

vapor, so that its heat is distributed through the atmosphere from a level of five miles or more down to sea-level; and about two-fifths, or 24 per cent., are absorbed in clouds, principally between levels of one and two miles. Thus it seems that little more than 20 per cent. of the sun-rays intercepted by the earth as a planet are absorbed directly to produce heat on its solid and liquid surface.

An even greater atmospheric obstruction occurs to terrestrial rays. Of the output from the earth's surface, about half is absorbed in clouds, and three-fourths of the remainder in water-vapor and carbonic-acid gas of the atmosphere, so that hardly more than 10 per cent. of the radiation of the earth's solid and liquid surface escapes directly to space. By successive radiations from place to place within the atmosphere, the energy does at length reach high levels where it is more free to escape from the earth. Yet the atmosphere plays strongly the part of the blanket upon the couch, or the asbestos covering upon the steam pipe, or still more accurately the glass cover over the hot-bed. In consequence of this blanketing effect of the atmosphere the mean surface temperature of the earth is probably 30° C. (54° F.) warmer than it would be if terrestrial rays passed freely from the earth's surface to space. Not only so, but the change of temperature between night and day is very greatly reduced by the same agency.

Experiments of Lord Rosse, Langley and others showed that in the brief period of a few hours during a lunar eclipse the moon's surface falls from a temperature well above freezing, even, perhaps, approaching that of boiling water, to a temperature far below freezing. As the moon is situated similarly to the earth as regards solar distance, but lacks an atmosphere, we readily see from this observation the great value of our atmosphere to equalize temperature. On the earth the maximum range caused by night and day, even in deserts, rarely exceeds 20° C. At most stations the mean daily range is less than 10° C.

Dependent as we are on food crops, which in turn depend

on restrictions of temperature range, it seems safe to conclude that human life would be impossible here if it were not for the tempering action of clouds, water-vapor and carbon dioxide, in restraining so strongly the escape of radiation from the earth's surface. These constituents of the atmosphere make hardly 3 per cent. of its weight, but they are the all-important agents for this purpose. Oxygen and nitrogen play little part in restraining terrestrial radiation, though they scatter the incoming shorter wave-length solar rays powerfully, and thus produce the brightness and blue color of the sky.

Many years ago Professor Hann, of Vienna, published an investigation of the variability of mean daily air temperatures from day to day. Ninety stations well distributed over the earth were considered. It may be said, speaking roughly, that the region of United States and Canada from the Great Lakes to the Coast Range, and from the Ohio River to Hudson Bay is twice as variable in climate as any other large area of the inhabited world outside of Asiatic Russia. But as shown in the accompanying table, when we consider the changes on a percentage basis, measuring our departures from the absolute zero where temperature begins, we get an impression of extraordinary stability rather than of changeableness. So great a degree of stability compared with the variableness of other quantities such as length of life, stature, weight and wealth of individuals is, indeed, almost unexplainable, in view of the variable elements we have been considering, on which temperatures depend. Despite variable screening substances which cut off 80 per cent. of incoming heat and 90 per cent. of outgoing heat, mean daily surface air temperatures in most parts of the world rarely vary 1 per cent. from day to day.

As we have seen, the complete cutting off of solar radiation at night by no means causes the earth's surface temperature to fall to the absolute zero This is because the darkness does not last long enough to permit the escape of more than a small fraction of the available heat of the earth. We have mentioned the powerfully hindering atmospheric constituents which cut down

the rate of loss of terrestrial heat, and now we may note conditions which govern the quantity of heat available to escape.

AVERAGE NUMBER OF DAYS PER YEAR IN WINTER, SPRING, SUMMER AND AUTUMN WHEN OCCUR VARIATIONS OF MEAN DAILY TEMPERATURE BETWEEN CERTAIN LIMITS EXPRESSED IN DEGREES C. AND ALSO IN PERCENTAGES OF ABSOLUTE TEMPERATURE (WHERE FREEZING IS 273° ABS. C.)

Station	Limits		Number of Days in			
	Degrees C.	Percentage	Winter	Spring	Summer	Autumn
Leavenworth, Kansas	0°0 to 1°5	0·0 to 0·5	21	24	29	26
	1·5 to 3·0	0·5 to 1·0	17	20	24	21
	3·0 to 7·5	1·0 to 2·5	29	32	25	30
	7·5 to 15·0	2·5 to 5·0	20	15	4	13
	over 15·0	over 5·0	3	1	0	1
Paris, France	0·0 to 1·5	0·0 to 0·5	42	46	45	46
	1·5 to 3·0	0·5 to 1·0	28	28	28	28
	3·0 to 7·5	1·0 to 2·5	19	17	18	16
	over 7·5	over 2·5	1	1	1	1
Sydney, Australia	0·0 to 1·5	0·0 to 0·5	50	45	47	58
	1·5 to 3·0	0·5 to 1·0	25	24	24	23
	3·0 to 7·5	1·0 to 2·5	15	19	19	10
	over 7·5	over 2·5	0	3	2	0

Available terrestrial heat varies greatly with the locality. On the water the surface layers if above 4° C. (39·2° F.) in temperature, contract by cooling, and becoming more dense sink down and are replaced by warmer water from below. Hence a great depth of water, at least 10 meters (33 feet), is available to give up heat. Moreover, the capacity for heat of water is very high, so that a given weight of water gives up about five times as much heat as the same weight of rock cooled through equal temperature difference. Furthermore, the cloudiness and humidity of the atmosphere is generally greater over the oceans than over the land. For all these reasons the daily and yearly changes of temperature are relatively very small over the oceans.

On land, especially desert land, the available heat is much less. No exchange of warm for cooled material being possible,

heat can only flow from beneath the surface by conduction. Soil and rock are such very poor conductors that no appreciable change of temperature takes place between night and day on land below a depth of 50 centimeters (20 inches). On account of this, the heat available to escape during the night over a land surface resides almost as much in the atmosphere as in the earth, unless the soil is very wet, so that oceanic conditions are to some extent duplicated. We see, therefore, the explanation of the great difference between oceanic and continental climates. The former have much the smaller changes of temperature from day to night and from summer to winter. Compare, for instance, the mean hourly and monthly temperatures of Timbuctu and Port au Prince, stations of nearly equal latitude.

MEAN HOURLY DEPARTURES FROM MEAN TEMPERATURES C.

Hours	Mid-night	2	4	6	8	10	12
	°	°	°	°	°	°	°
Timbuctu	−4·1	−5·6	−6·8	−7·7	−2·8	+3·2	+6·9
Port au Prince	−2·6	−3·2	−3·7	−3·8	−0·6	+2·9	+4·7

Hours	2	4	6	8	10	Mean	Range
	°	°	°	°	°	°	°
Timbuctu	+8·5	+7·4	+3·4	−0·1	−2·4	29·2	16·2
Port au Prince	+4·5	+3·1	+1·1	−0·8	−1·3	25·9	8·5

MONTHLY MEAN TEMPERATURES C.

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Range
	°	°	°	°	°	°	°	°	°	°	°	°	°
Timbuctu	21·8	23·8	28·1	32·5	35·0	34·2	32·7	31·1	31·8	31·0	26·8	21·4	13·6
Port au Prince	24·1	24·6	25·1	25·9	26·0	27·1	27·6	27·3	26·7	26·3	25·6	24·4	3·5

Thus Timbuctu in the Sahara Desert has twice the daily range and four times the yearly range of temperature that Port au Prince on the coast of Haiti does.

Besides the atmospheric blanket and the heat capacity of the surroundings, a time element affects the range of temperature changes attending fluctuations of solar radiation. A rotating disc having a sector of its surface cut away is often used to diminish the apparent intensity of a beam of light. If the disc is rapidly turned, the eye can not detect the changes from light to darkness, and *vice versa*. The effect seen is that of a light of diminished brightness. But if the speed is reduced, fluctuations become more and more noticeable, till at slow speed the full change from light to darkness is apparent. Similarly it should be with changes of the earth's temperature produced by changes of solar radiation. If the solar changes were sufficiently slow, they should produce complete and equal temperature changes at all stations, whether desert or oceanic, provided no secondary changes of cloudiness or humidity, or other variable elements, accompanied.

How large a terrestrial temperature change ought then to follow a slow increase of 1 per cent. in solar radiation?

Evidently the earth's temperature should increase until its own radiation to space becomes 1 per cent. greater. Bodies which emit radiation by virtue of their temperature are of more or less radiative efficiency, but all natural bodies fall short of the theoretical "perfect radiator." This instrument is closely approached by an enclosure with a minute opening for the escape of its radiation, and with walls of equal temperature. For the "perfect radiator" the emission is proportional to the fourth power of its temperature above absolute zero. It is known that water is very nearly a perfect radiator at ordinary temperatures, and moist soil also. Hence, we shall not be far wrong in supposing that the radiation of the earth varies as the fourth power of its absolute temperature. Thus in order to increase its radiation 1 per cent. we should expect an increase of the earth's mean temperature from 287° Abs. C. to 287·7° Abs. C.; for the fourth powers of these numbers differs by 1 per cent. For very slow fluctuations of solar radiation of a few per cent. range we, therefore, expect 0·7 as many degrees change

of terrestrial temperature as the number of per cent. change of solar radiat on.

Compare this with the yearly range at Timbuctu. Taking into account the obliquity of the rays and the distance of the sun, the yearly range of solar radiation at north latitude 16° 49′ is 34 per cent. Corresponding to this we expect 24° temperature change. The actual change is 13·6° at Timbuctu. From these figures we conclude that, even for desert climates, changes of solar radiation must be of several years period to produce their maximum temperature effects. It seems probable that solar radiation changes attending the eleven-year cycle of sunspots may be sufficiently slow to produce nearly full temperature effects, not only in deserts but over the world in general.

What changes of solar radiation attend the sunspot cycle? Owing to effects of clouds, haze, humidity and dust in the atmosphere, it is not possible to determine changes in the solar emission of radiation, without using complicated apparatus and methods of observing, and conducting the research at more than ordinarily favorable stations. In short, no observations competent to determine real solar radiation changes were made prior to the year 1905. Since then suitable measurements have been conducted for several months af each year (excepting 1907) by the Smithsonian Astrophysical Observatory, at a station on Mount Wilson, near Pasadena, California. The results obtained give values of the so-called "solar constant of radiation." This is the quantity of energy per square centimeter per minute received at right angles to the solar beam in free space at the earth's mean solar distance. The following table shows the yearly mean values, usually representing about 100 days each, as obtained at Mount Wilson in the months June to October, inclusive.

SUN-SPOTS AND SOLAR RADIATION

Year	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1914
Solar constant	1·956	1·942	——	1·936	1·918	1·921	1·923	1·940	1·907	1·948	1·949
Spot number	62·5	53·8	62·0	48·5	43·9	18·6	5·7	3·6	1·4	9·7	46·0

These figures do not indicate a very close dependence between the prevalence of sun-spots and the intensity of the sun's emission of radiation, yet they do seem to indicate that there is a tendency to increased radiation when the sun-spottedness is rapidly increasing, or at maximum, compared with the period when the sun-spottedness is rapidly declining or at minimum. Contrasting from this point of view the mean values for the years 1905–6–8 and 1914–15 with those for 1909–10–11–12–13, we have : —

	5 Active Years	5 Inactive Years
Mean solar constant	1·946	1·922
Mean sun-spot number	46·1	14·6

If this be regarded as typical, we learn that an increase of 25 sun-spot numbers is attended by 1 per cent. increase of solar radiation. The average range of sun-spot numbers in the 15 sun-spot cycles from the year 1750 to the year 1906 was 90, so that on the basis just stated an average sun-spot maximum might be expected to be attended with 3·6 per cent. more emission of solar radiation than the minimum of sun-spot activity. This, according to our preceding conclusion, might be expected to be attended with a general *increase* of terrestrial temperature of 2·5° C.

The dependence of sun-spots and terrestrial temperature has lately been investigated by the method of correlation (of which we shall say more below) by Dr. Walker, director general of the Indian Meteorological Department. His studies deal with 97 stations in all parts of the world and show that with the exception of northwestern Africa, the west and north coasts of

the Eurasion continent, Bermuda, New Zealand and a part of the Indian Ocean, the world in general has *lower* temperature at sun-spot maximum than at minimum. Numerical values have been obtained for a great number of stations, and for long periods of years, by several investigators, but notably by Köppen. He finds that for the interval from 1815 to 1873 the average *decrease* of terrestrial temperature at sun-spot maximum was 0·7° C., and for the interval 1873 to 1910, 0·5° C. The difference may well be attributed to the greater average intensity of the sun-spot maxima in the former interval.

Here then is a well-established paradox. Increased solar activity, as indicated by sun-spots, is attended by decreased terrestrial temperature. It has been suggested, but not demonstrated, that the explanation lies in an increase of cloudiness at sun-spot maximum; and that the increase of cloudiness is caused by the penetration of the atmosphere to lower levels by electric ions shot from the sun with greater power at maximum solar activity.

Besides these variations of solar radiation from one year to another, the Smithsonian observations indicate fluctuations which run irregular courses, often in a week or ten days. The true solar existence of these changes has been confirmed in several ways, among others in the years 1911 and 1912 by making the measurements simultaneously in California and Algeria, separated by a third part of the earth's circumference. More recently it has been found that the changes are accompanied by variations of brightness over the sun's disc. Dr. Bauer, too, has shown that fluctuations of the earth's magnetic field accompany them.

As an example of these changes, see the following observations of September in the year 1911.

Date September	3	4	5	6	7	8	9	10	11
Solar constant value	1·888	1·906	1·917	1·960	1·938	1.993	1·948	1·908	1·892

The observed range here is 5½ per cent. in eight days. What effect should this produce on the weather?

Recalling that a change of 100 per cent. in twenty-four hours produces a temperature change of 8·5° C. at Port au Prince, and 16·2° C. at Timbuctu, while 34 per cent. change in 365 days produces 3·5° C. at the former and 13·6° C. at the latter of these two stations, we should expect that for the average station a solar radiation change ranging 5 per cent. in eight days might produce about 0·8° C., or nearly 1·5° F., temperature fluctuation. But as we have seen that for many stations the increase of solar radiation, which seems naturally to accompany the great solar activity of sun-spot maximum, is attended by *lower* terrestrial temperatures, we may not be surprised if things turn out less simply than expected in regard to the short interval solar fluctuations.

The subject has lately been investigated by Dr. H. H. Clayton, of Argentina, formerly of Blue Hill, Mass. In such an investigation a natural procedure would be to make two superposed curves, one to show the change of solar radiation day after day, and the other the change of temperature. The trouble with this method is that there are so many influences that operate on the weather, apparently haphazard, that their combined effect often masks the influence under investigation. Accordingly, Dr. Clayton employed the mathematical method of correlation, which has come into general use in biological researches. In this method two functions, like the diameter and circumference of a circle, that are related so intimately that the increase of the one depends only on the increase of the other, are said to have a correlation co-efficient + 1. Two functions, like the heights of two ends of a balance, which are so connected that increase of one depends only on decrease of the other, are said to have a correlation co-efficient − 1. Between these perfect degrees of positive and negative correlation lie all degrees of dependence, and a co-efficient of correlation, zero, indicates that the variables are unrelated. As in other investigations, it is valuable to determine the probable error of each co-efficient

of correlation, and one considers a correlation standing alone as demonstrated when its co-efficient is numerically three or four times its probable error. A group of correlations may, however, so obviously support each other as to lend certainty to the correlation of individuals of the combination, though these individual members would otherwise be doubtful in view of probable error.

Dr. Clayton determined for about fifty stations, well distributed over the globe, correlation co-efficients connecting temperatures with solar-constant values determined at Mount Wilson in 1913 and 1914. As he thought it likely that the terrestrial influence of solar changes would be deferred, he computed the correlations not only for identical days, but for the 1st, 2nd, 3rd, 4th and 5th days thereafter. Here are examples of the largest correlation co-efficients obtained.

Days Following Solar Observations					0	1	2	3	4	5
Station	Latitude		Longitude		Correlation Co-efficient					
Pilar	31°	39 S.	63°	5 W.	0·32	0·51	0·54	0·48	0·33	0·13
San Diego	32	43 N.	117	10 W.	0·18	−0·10	−0·29	−0·50	−0·52	−0·44

Probable error about ± 0·07.

From this we see that at Pilar, Argentina, *increase* of temperature followed increase of solar radiation, and the maximum effect occurred after one or two days, while at San Diego, California, *decrease* of temperature followed increase of solar rad a-tion, and the maximum effect occurred after three or four days. The co-efficients of correlation at maximum are fully seven times the probable error numerically, so that the connection is well assured. For other stations different values, some positive, others negative, were obtained, ranging down to zero.

When marked on the map the stations of positive and negative correlations were found to arrange themselves very definitely in zones. Speaking roughly, in the zone within the tropics, but broadening over land areas and narrowing over the

oceans, the correlation is positive, and so also in the arctic and antarctic zones, and extending down the east coast of North America. In the remainder of the world, comprising the great temperate zones, the correlation is negative.

A similar investigation, but less extensive, was made by Clayton on the relation of atmospheric pressure to solar radiation. Similar zones seemed to be indicated, but where temperatures rose after increases of solar radiation, pressures fell, and *vice versa*.

For several of the stations, Clayton's investigation indicates the actual numerical changes in temperatures which follow a change of solar radiation. From the average of all the decided changes of solar radiation, I find from his curves that for 1 per cent. solar change there was 5·2° C. average change in temperature at Pilar, 1·5° C. at Manila, and 6·3° C. negative change at Winnipeg. Other stations would appear to give equally surprisingly large results. Clayton's figures, however, relate to maximum daily temperatures. It may be reasonably supposed that the changes of mean temperature corresponding to 1 per cent. increase of solar radiation would be half as great, or + 2·6°, + 0·75° and − 3·15° C., respectively, at the three stations. We had been led to expect almost surely not more than 0·7°, and probably not more than 0·2° C.

Five thoughts are suggested by this remarkable result. First, that the figures ought to be confirmed by tests extending over other years and other stations. Second, that if confirmed they will indicate that secondary processes are set going in the atmosphere by small changes of solar radiation, which, by altering the atmospheric blanketing effect, magnify in some stations, and reverse in others the natural direct effects of the solar fluctuations. Third, that if such large changes of temperature are thus caused, investigation may be apt to reveal important effects of solar fluctuations on the winds, cloudiness and precipitation. Fourth, that since the outstanding unexplained departures from mean daily temperatures, as illustrated above for Leavenworth, Paris and Sydney, are seldom of much greater

magnitude than the changes which are found by Clayton to be produced by changes in the sun, and as the maximum effects of solar changes follow from one to five days after the cause, depending on the latitude of the station, it may be possible that a very large proportion of weather changes will become predictable for some time in advance, if daily measurements of the solar emission shall be secured. Fifth, that since daily solar-constant measurements of sufficient accuracy can only be had by establishing several new observing stations in the most cloudless regions of the earth, at an initial expense of from $5,000 to $10,000 each, and continued expense of from $5,000 to $10,000 per year each, the occupation of this promising field in forecasting is likely to be deferred until after the war is over.

At present the Smithsonian Institution is alone making the required measurements, at Mount Wilson, California, and Hump Mountain, North Carolina. Weather conditions are not sufficiently favorable at either station to warrant the expectation that on half the days in the year the solar radiation will be properly measured. A projected station in South America has been deferred on account of war conditions, but may soon be occupied. A bequest of half a million dollars to the Smithsonian Institution would enable it to handle adequately this apparently exceedingly important problem.

SEEN IN A FOURTEEN-INCH REFLECTOR

By A. R. Hassard

ON the night of October 25, 1917, I spent some time in using my new 14-inch reflector. The tube of this instrument and, indeed, its entire mounting I made a number of years ago, —about the year 1910. The glass forming the large mirror I ground last winter. It is 14¼ inches in diameter and is about one inch or a little more in thickness. The focal length of the mirror is about 121 inches, thus necessitating a tube ten feet in length. I use a ladder to ascend to the eyepiece for making the more elevated observations. With this instrument I observed the moon, then approaching the full, and it was a splendid object when viewed in the telescope. I used eye-pieces giving magnifications of about 100, 150 and 300 diameters, principally. There is a curious formation on the moon about midway between Plato and the exceedingly luminous crater Aristarchus, which for years has excited my deepest interest. When the moon is about eight or nine days old, this object comes into view on the terminator of the moon, and projects away out into black darkness. In that position it very much resembled a bright handle, similar to the handle on the cover of a large dish or receptacle. During the approach of this object into daybreak on that portion of the moon, it continues to preserve its handle-like appearance, until eventually base, as well as summit, of the projection is bathed in the light of the sun. I have observed this object with most attentive care, with a view to ascertaining, if possible, its construction, and I am of the opinion that there is much ground for asserting that the luminous height is really the roof of a deep cave running horizontally in to some mysterious recess in the moon. There is no evidence that this cave descends into the depths of the moon, but the existence of a vast cave seems to be

a reasonable, and, indeed, in my judgment, the only explanation of the luminous handle-shaped projection which for many hours once a month stands out so conspicuously in solitary splendor on the surface of the moon. I have examined the same object long after that part of the moon's surface is bathed in light, and while the appearance is consistent with the existence of a cave at that spot, there is nothing unusual about its appearance after the moon's terminator have moved some distance away. It then all dissolves into the silvery splendor which floods the face of the moon when the rays of the sun are pouring down almost vertically upon it.

It is, of course, impossible to count all the different objects which are visible on the moon as viewed through the 14-inch telescope. I have seen names given to about 500 lunar prominences, craters, dried-up seas and plains, but I would think that easily 5,000 of such objects could be seen and individually identified, if only an observer has the patience to persevere in viewing and counting them. One night quite recently I counted fifty tiny volcanic craters within a very small space. I am sure there were on the lunar surface 100 other spaces equally dotted with vast numbers of these small circular formations.

The part of the moon's surface near Tycho, from which radiate numberless streams of some substance which evidently has flowed from one radiating point, is marvellously interesting as a spectacle. Multitudes of craters of every size, from nearly one hundred miles in diameter down to very small dimensions, cluster in almost boundless profusion at this spot, and cover a very large area. The roughness of the lunar surface there, when compared with parts of the moon at a half or a third of its diameter away is as if one were to compare the Rocky Mountains with the level prairie of the central provinces of Canada.

I also viewed Jupiter in the 14-inch telescope, and its dusky belts were noticeable. Its flattened polar regions were singularly manifest indeed. With a large glass one actually does see something worth while looking at on a planet like Jupiter, and it is a great source of delight to watch it and its little family of

intensely bright moons out there in the vault of the skies. Viewing that planet and its constantly changing attendant satellites night after night cannot but arouse the deepest wonder that such a mighty body, with its tireless attendants, should hang out there in the midnight heavens for countless ages, pursuing the same uninterrupted journey, for some mysterious purpose, which humanity very likely never shall know, that it pursued before Miltiades led the Greeks at Marathon, or Cæsar ever cast his delighted eye upon the ancient English shores.

On the night of November 1, 1917, at 11.30 the four large moons of Jupiter were all on the side of the planet known as the preceding or westerly side.

I also viewed in the 14-inch glass the trapezium in Orion, which is a small arrangement of four small stars buried in the very heart of the great nebula in that famous constellation. No two sides of the four-sided figure formed by those four minute stars are of the same length, and the angles at the four corners are all of irregular size also. The fourth star is very minute, perhaps of the ninth magnitude. The four are a little difficult of detection to the unpractised eye, because of the fact that they lie in the bed of the soft white nebulous substance, and are somewhat lost in its luminosity. Still they are quite visible, and a power of 300 throws them quite noticeably apart. The fathomless distance at which they exist far into the heart of that nebula, according to recent investigations, fills the mind with amazement bordering on despair. Almost clinging closely to one another, as the telescope would indicate or suggest, they are so widely separated that the human mind staggers when it attempts to contemplate the magnitude of the distance that they are actually apart.

I was delighted to see that the sextuple star, known as Sigma Orionis — a star which is at right angles with the most southerly of the three stars in the belt of Orion, and not much more than half the distance from that most southerly star that it is from its nearest neighbor of the three, a star also which appears as single to the naked eye, — appeared not only as a

multiple star with six components, but I was able with the 14-inch telescope to divide its very faintest star into two close components. Each of the two cannot be much more than of about the tenth or eleventh magnitude.

The constellations of Taurus and Orion are filled with telescopic wonders, and during the winter nights much profit as well as amusement can be derived from even a hasty study of the many double stars, clusters, nebulas, and other objects of astronomical interest which the telescope constantly reveals in these brilliant constellations.

TORONTO, ONT.

MEETINGS OF THE SOCIETY

At Toronto

October 9.—The first of the regular meetings of the autumn term of the Royal Astronomical Society of Canada at Toronto, was held in the Society's Rooms, 198 College St. Mr. A. F. Hunter, M.A., in the chair.

Reports of observations made during the past summer were received from Mr. Hunter, Mr. A. R. Hassard and Mr. J. R. Collins.

Mr. Hunter reported having observed from the vicinity of Barrie, Ont., many of the auroral displays that have been visible during the summer, particularly the displays of June 12, and July 21 and 22. On the night of July 22 lightning was observed in another portion of the sky simultaneously with the auroral display. Mr. Hunter had also noted that solar halos and lunar halos were numerous during the past season.

Mr. Collins reported having observed the "Boreal Crown" on the nights of July 21 and August 9.

Mr. Hassard reported having observed the activity of sunspots during the months of June and July and noted that there had been two full moons in the month of September, an occurrence that had not taken place in the month since 1896.

Dr. Fraser reported the observation of a double rainbow of unusual persistence.

Under "Notes and Queries," theories regarding the cause of the aurora and the low temperature of the higher strata of the earth's atmosphere were discussed by the members.

October 23.—The meeting was held in the Society's Rooms, 198 College St. Mr. J. A. Paterson in the chair.

President E. E. Braithwaite, M.A., Ph.D., Western University, London, Ont., and

Mr. Thomas B. Hurst, 158 Westmount St., Toronto,

were elected members of the Society.

Rev. C. V. Pilcher reported on a very brilliant aurora at Murray Bay, July 31, 1917; an interesting discussion on the aurora followed these remarks.

Mr. A. F. Hunter referred to the memorial to be unveiled at Brantford on October 24, 1917, in honor of Graham Bell, the inventor of the telephone.

Rev. C. V. Pilcher was then called on for his paper on "Early Recollections of the Stars," and he gave to the Society a very interesting résumé of his childhood studies in astronomy. He referred briefly to Icelandic astronomy and it is hoped that he will favor the Society with a paper on this subject at his earliest opportunity.

November 6.—The meeting was held in the Society's rooms, 198 College St. Professor Chant in the chair.

Mr. Charles L. Early, Sac City, Iowa, was elected a member of the Society.

Mr. Wallace referred to a recent large sun-spot group quoted by Mr. Maunder as being the largest spot for 48 years. He then suggested a possible relation between sun-spots and the position of the planets.

Mr. A. F. Hunter gave the paper of the evening on "Special Forms of Halos and Rainbows." By means of lantern illustrations the lecturer showed the various forms of halos and explained how they were produced. He then had projected on the screen a series of halos of unusual form, most of which were seen from Barrie, Ont., and offered explanations of them which were well received by the members.

W. E. W. Jackson, *Rec.-Sec.*

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

October, 1917

Temperature.—The mean temperature was below average in all parts of the Dominion, excepting the Interior of British Columbia and Eastern Nova Scotia. The negative departures were very large in Saskatchewan, Manitoba and Ontario, amounting to between 4° and 9°.

Precipitation.—Precipitation was excessive everywhere east of Lake Huron the total in many districts being double the average amount. From the Great Lakes westward it became gradually less, and in the Western Provinces where it was largely in the form of snow, average figures were reported. In British Columbia the departure was mostly in defect, but not to any marked extent.

Temperature for October, 1917

Station	October		Station	October	
	Highest	Lowest		Highest	Lowest
Yukon			Kenora	59	15
Dawson	46	- 4	Kinmount	60	18
British Columbia			Kingston	62	29
Atlin	54	7	Kitchener	64	25
Agassiz	74	31	London	66	23
Barkerville	60	9	Lucknow	67	22
Kamloops	84	26	Markdale		
New Westminster	71	30	North Gower	70	20
Prince Rupert	64	34	Oshawa	65	27
Vancouver	67	32	Ottawa	63	26
Victoria	69	37	Paris	68	24
			Parry Sound	60	26
Western Provinces			Peterboro'	61	25
Battleford	71	- 5	Port Arthur	58	18
Calgary	80	7	Port Burwell	62	28
Edmonton	76	10	Port Dover	60	27
Medicine Hat	76	8	Port Stanley	61	24
Minnedosa	68	- 8	Queensborough	61	21
Moose Jaw	70	5	Ronville	57	24
Oakbank	62	6	Southampton	67	26
Portage la Prairie	56	8	Sundridge		
Prince Albert	68	4	Stonecliffe	58	26
Qu'Appelle	62	7	Stony Creek	71	27
Regina	66	4	Toronto	62	29
Saskatoon	73	- 7	Uxbridge	60	25
Souris	69	9	Wallaceburg	66	25
Swift Current	70	- 2	Welland	70	26
Winnipeg	64	8	White River	58	- 1
Ontario			*Quebec*		
Agincourt	64	27	Brome	68	21
Aurora	60	25	Father Point	64	22
Bancroft	65	18	Montreal	64	32
Barrie	64	28	Quebec	69	30
Beatrice	61	21	Sherbrooke	68	26
Bloomfield					
Chapleau	54	5	*Maritime Provinces*		
Chatham	67	26	Charlottetown	68	34
Clinton	68	24	Chatham	62	30
Collingwood			Dalhousie		
Cottam	69	21	Fredericton	65	28
Georgetown	63	25	Halifax	66	32
Goderich			Moncton	68	23
Grimsby	70	28	St. John	63	34
Guelph	64	23	Sussex	65	28
Haliburton	61	18	Sydney	66	32
Huntsville	61	21	Yarmouth	68	29

Earthquake Records by the Milne Seismograph

TORONTO

Sir Frederic Stupart, Director.

P.T. = Preliminary Tremors, S. = Secondary Waves, L.W. = Large Waves, A.C. = Air Currents. Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1917	P. T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
		h m	h m	h m	h m	h m	mm	
1769	Oct. 7			15 26·7?) 15 45·2)	A.C.	A.C.	0·3?	
1770	" 13			5 00·3		5 06·6	0·05	
1771	" 19	16 39·8) 16 42·7)	16 46·7) 16 49·3)	16 51·6	16 57·0	A.C.	1·3	P. and S. very doubtful.
1772	" 20			18 35·6) 18 44·3)			0·2	A. C. going on.
1773	" 22		7 35·2?	7 36·4	7 37·6	8 24·4	0·8	
1774	" 23			8 04·3?			0·05	A. C. going on.
1775	" 28			13 40·6	13 46·6	14 10·5	0·8	
1776	" 28			17 52·2				Other phases lost attending inst.
1777	" 29			21 41·5?) 21 47·3)	21 51·7	22 58·3	0·3	

Boom period 18 seconds. Pillar inclination 1mm. = 0″·50.

VICTORIA, B. C.

F. N. Denison, Superintendent.

No.	Date 1917	P.T. Comm.	S. Comm.	L.W. Comm.	Max.	End	Max. Amp.	Remarks
		h m s	h m s	h m s	h m s	h m s	mm	
1782	Oct. 7	15 21 34	15 25 38?	15 30 35	15 35 33	15 49 55?	0·5	2,490 km.?
1783	" 13			4 40 00) 4 43 24)		4 50 06	0·1	Minute and sharp v.bs.
1784	" 19	16 44 24	16 51 20	17 00 46	17 07 42	17 36 28	0·5	5250 km.
1785	" 20			18 15 09	18 21 42	18 29 39	0·2	
1786	" 22	7 42 06?		7 51 01	7 56 28	8 21 46	0·4	P. may be S. phase.
1787	" 23	8 05 58		8 11 25	8 14 53	8 19 51	0·2	
1788	" 28			13 57 20		14 09 20	0·05	
1789	" 28			17 50 44		18 14 14	0·1	
1790	" 29	20 59 20	?	21 17 42	21 30 35	21 46 57	0·3	

Boom period 18 seconds. Pillar inclination 1mm. = 0″·54

Vertical Seismograph

Date 1917	P.T. Comm.	S. Comm.	L.W. Comm.	Max.	End*	Max. Amp.	Remarks
	h m s	h m s	h m s	h m s	h m s	μ*	
Oct. 19				17 07 00		1	*True earth movement.

J. V.

MAGNETIC OBSERVATIONS

SEPTEMBER, 1917

At Agincourt during the month of September the Magnetic Force was moderately disturbed on the 3rd, 5th and 9th, more particularly in the Vertical Component. During the remainder of the month the curves were calm or very lightly disturbed. At Meanook moderate disturbances were recorded on the 3rd, 9th and 30th, the greatest occurring on the 9th instead of the 5th as at Agincourt.

Numerous small sun-spots were recorded throughout the month and one large group was central on the sun's disc on the 22nd.

Auroræ were recorded in most parts of Canada from the 20th to 23rd and locally from the 8th to the 15th.

AGINCOURT MAGNETIC OBSERVATIONS

Lat. 43° 47′ N.; Long. 79° 16′ W.

July, 1917		D. West	H	Z	I
		° ′	γ	γ	° ′
	Mean of Month	6 36·5	15938	58426	74 44·5
	Maximum	7 12·8	16087	58600	
	Date of Maximum	5	5	5	
	Minimum	6 11·8	15739	58173	
	Date of Minimum	2	5	5	
	Monthly Range	1 01·0	348	427	
Mean Daily Amplitude	From hourly readings	15·0	64	25	
	From means of extremes	22·1	93	51	

MEANOOK MAGNETIC OBSERVATIONS

Lat. 54° 37′ N.; Long. 113° 21′ W.

July, 1917		D. East	I
		° ′	° ′
	Mean of Month	27 47·0	77 54·8
	Maximum	29 09·8	
	Date	9	
	Minimum	26 57·5	
	Date	9	
	Monthly Range	2 12·3	
Mean Daily Amplitude	(From hourly readings	15·1	
	(From means of extremes	39·0	

H and Z are given in Gammas. (1 γ = 0·00001 C.G.S.).

All results are reduced to International Magnetic Standard.

The value for I is the mean of all the observations made during the month without regard to the time of day.

W. E. W. J.

ASTRONOMICAL NOTES

THE SPIRIT OF MODERN SCIENTIFIC RESEARCH.—At the University of Chicago I have a friend by the name of Braested, who is an Egyptologist. Braested tells me that he and his fellow Egyptologists have proof that less than 100 years elapsed from the time when, about 5,000 years ago, the Egyptian knew so little about building that the best they could do was to pile crude rows of uncut stone around their dead, to the time when some of the great pyramids were built, structures which represent in some ways the height of the builder's art, structures on which the surfacing is so perfect that huge granite blocks 18 ft. on a side are joined together without cement, and with not as much as 1/100 of an inch of space anywhere between them. That kind of engineering we do not do now — luckily we do not have to do it, but it is doubtful if we could do it if we would. I am mentioning this to bring out the fact that Egypt at that time got the key to a certain kind of development, and pushed that development to a marvellous degree of perfection. Indeed, there was in that century, so Professor Braested says, an industrial progress which has never been equalled at any time in the world's history until within the last 100 years, when the modern industrial revolution set in.

Go now to Greek history, and we find the same sort of a situation. About 500 B.C. the Greeks got the key to a certain type of progress, and they developed a civilisation which, on the intellectual side and on the artistic and æsthetic side, has never been equalled. The Greeks, like the Egyptians, got the key to a certain kind of civilisation, and they worked it out to marvellous perfection, but in neither case did these men or these races go on ; they did not open up new fields ; they did not tap new mines. Their civilisation came to an apex and then decayed,

and the question has often arisen in your minds, as it has in mine. Is this age in which we are living going to follow in the same way? Have we risen to a maximum? Have we had a period of marvellous development, which is going to be followed by one of decay and stagnation, or are we going to ascend to higher and higher levels? No man can answer that questson; but this I know, and this you know, that it was wholly unnecessary that Greek civilisation or that Egyptian civilisation should stop when it did. If they had developed the modern scientific spirit, the spirit of search for new phenomena and new methods, they could have found them. There were plenty of new mines for them to tap, plenty of unexplored fields to search out. But they did not do it. As for us, I feel as sure as Shakespeare did that "there are [still] more things in heaven and earth than are dreamed of in our philosophy," and if we stop it will be because we have forgotten the lesson which Galileo first tried to teach, and which we have been learning in the last one hundred years, and that is the lesson of research. It is the lesson, the philosophy, the method, and the faith of modern physics. That is our hope, and if we keep that, if we don't call in our scouts because the rewards are larger in the applications, then I haven't any doubt that our civilisation will go on; and if we do call in our scouts here in this country, then our civilisation will give place to that of some other country which does not do so, but which learns the value for the human race of the spirit of modern scientific research.—Conclusion of a lecture on "Modern Physics," by PROFESSOR MILLIKAN, in *Proceedings* of the American Institute Electrical Engineers.

JUPITER.—If radiant Venus is the star of the evening and the morning, the white goddess of love and beauty; if Mars with the red rays personifies war; if Mercury, which flies alternately and swiftly on all sides of the sun, is indeed a messenger of Apollo; if Saturn, whose revolution, long and slow, of thirty terrestrial years, at the frontiers of the ancient system of the world, is the god of time and destiny; Jupiter, the planet of the ecliptic, who reigns in his royal route, is particularly the domin-

ant star of the starry procession of night, and the discoveries of modern astronomy have not at all diminished the interest which he was able to offer to our ancestors in the time of fable and astrology. Here again, as everywhere, reality is superior to illusion.

Let us hail in Jupiter the symbol of the future. Behind him, in the constellations, there are some stars whose light, departing at the time of the Trojan war, reaches us only to-day. Thus, in the same book of the sky, the past and the future are united and tell us that, if there is anything interesting in human life, it is the thought, it is the mind that contemplates the universe, which lives intellectually, and without which all nature would be only the sport of an unconscious automation. We have said it more than once, and we shall not be able too much to repeat it, especially on commencing this new year in which it seems that brutal matter crushes all the nobleness of the mind.—CAMILLE FLAMMARION, *Popular Astronomy*, November, 1917.

SOME OBSERVATIONS OF AURORÆ AT MOUNT HAMILTON.—It is seldom that the people of central California see an aurora. In fact, the phenomenon is unknown to essentially all who have lived only in this part of the world. The month of November, 1893, at Mt. Hamilton, was marked by the presence of auroræ on several nights, though they could not be called bright ones in comparison with those visible in the high latitudes of North America and Europe. A few additional auroræ were observed in the winter of 1893-4, mostly as low faint arches in the north; their upper borders were usually less than 12° above the horizon. Similar very faint illuminations of the northern sky were observed a few times in the following twenty-four years, but after November, 1893, I do not recall seeing an aurora bright enough to be noticed by people in general until early in August, 1917; however, it is possible that a few such did occur.

Although auroræ are so seldom visible from Mt. Hamilton, it seems certain that the sky is completely covered with faint auroral light at all times. In 1893, I was led to conclude that the green line in the auroral spectrum may be seen on any dark clear night

in any part of the sky. I confirmed this on several nights in 1893, 1894 and 1895, again in 1908, and at other times. In fact, I never failed to see the green line *easily* when I looked for it.—W. W. CAMPBELL, *Publications Astronomical Society of the Pacific*, October, 1917.

THE COMMENCEMENT OF THE ASTRONOMICAL DAY.*—The civil day begins at midnight, the astronomical day at noon, twelve hours later. Thus, a meeting called for 9 a.m. July 4, civil time, would convene on July 3^d, 21^h, astronomical time; one called at 3 p.m. July 4, civil time, would convene on July 4^d 3^h, astronomical time. The inconvenience attaching to the use of these two systems of time-reckoning has long been recognised and from time to time proposals have been made to adopt the civil day in astronomical ephemerides and to do away entirely with so-called astronomical time.

This proposition has again been brought forward by Sir F. W. Dyson, Astronomer Royal, and Professor H. H. Turner, of Oxford, in a letter published in the July number of the *Observatory*. The writers invite astronomers to send to one of them expressions of their opinion of the desirability of the change. Acting upon this suggestion, the American Astronomical Society, at its recent meeting at Albany, appointed a committee to consider the question and make a report.

There are many arguments in favor of adopting the civil day in astronomical ephemerides; and the only objection of any consequence is the one pointed out in the letter referred to, that it would introduce discontinuity into astronomical records. This objection is not serious enough to count against the advantage of the change.

It is probably too late to secure any general agreement to the proposal in time to adopt it in nautical almanacs for 1920, but it would seem possible to introduce it at the next "round date," 1925, if astronomers everywhere will promptly voice their opinions in regard to it.—R. G. AITKEN, *Publications Astronomical Society of the Pacific*, October, 1917. J. R. C.

* See "Notes and Queries" of this JOURNAL for October, 1917.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

OBSERVING THE BIRTH OF A SUN-SPOT

In his short paper in last month's issue describing his summer observations Mr. A. R. Hassard remarks that he did not recall learning that anyone had ever actually witnessed the outbursting of a sun-spot (p. 377). Mr. Andrew Elvins informs the present writer that he has observed this phenomenon many times, and that on various occasions he has given an account of the history of spots as traced by him from day to day. In the TRANSACTIONS of the Astronomical and Physical Society for 1892 is an account of a fine group of spots seen in July, 1892, while in the *Proceedings* of the Canadian Institute for 1899 is the history of a group of spots which appeared in September and October, 1898. Mr. Elvins began making telescopic drawings of the sun before 1860, and has a large collection of them extending from that time almost up to the present. Indeed, during the past summer, when in his 95th year, he made observations of solar halos and auroræ.

THE SPECTRUM OF LIGHTNING

In *Bulletin* 79 of the Lowell Observatory, Dr. Slipher presents measurements of the spectrum of lightning as photographed by him at Flagstaff. In his paper is a list of previous publications on this subject, and I was surprised not to see a reference to the paper by A. Steadworthy, published in this

JOURNAL (Vol. VIII., p. 345, 1914), which includes a fine photograph and a measurement of wave-lengths. The essential part of the paper is quoted by Professor McAdie in his recent book on "Aerography".

Dr. Slipher finds that the spectrum is practically that of air. The lines are, with few exceptions, those due to the elements nitrogen and oxygen.

WORK AT HARVARD OBSERVATORY

The 71st Annual Report of the Director of Harvard College Observatory for the year ending September 30, 1916, contains some interesting facts. Three large pieces of work are in progress, namely, the New Draper Catalogue, the determination of photographic magnitudes and the observation of variable stars. The first-named continued under the supervision of Miss Cannon, the total number classified being 241,193. A considerable part of copy for the printer has been prepared and the first four hours of R.A. will form Volume XCI. of the *Annals*. Thirteen new variable stars have been found, while two stars, + 43° 33′ and S Cephei are so red that their brightness when photographed with yellow and blue light amounts to five magnitudes. The spectra of red stars are photographed by using plates stained with pinacyanol. At Cambridge the total number of photographic plates exposed was 6664, while at the Arequipa Station in Peru the total was 4849.

The determination of photographic magnitudes has continued under the supervision of Miss Leavitt, and the magnitudes of sequences in the Harvard Standard Regions are nearly completed. The total number of estimates of magnitudes is about 80,000.

The work on variable stars has also been materially extended. Over 9,100 settings with the polarizing photometer have been made, while the British Astronomical Association and the American Association of Variable Star Observers have contributed about 12,000 observations.

DEATH OF SIR WILLIAM JAMES HERSCHEL

The name of Herschel is of surpassing interest to astronomers, and immediate attention was consequently attracted to the announcement that on October 24 Sir William James Herschel had died. He was the grandson of the great Sir William and son of the almost equally distinguished Sir John Herschel. He was born in 1838 and from 1853 to 1878 was in the civil service in India. In 1859 he discovered the use of finger prints and used it as a means of identification in Bengal. He was the author of "The Origin of Finger Printing."

MOUNTAIN SITES FOR OBSERVATORIES

The distinguished success of the Lick and, later, of the Mt. Wilson and the Lowell Observatory, has led to the general belief that a mountain summit is the ideal site for an observatory. But this is not by any means correct. Mr. John Evershed, of the Kodaikanal Observatory in India, gives in the November number of *The Observatory* an account of some investigations which he has made at the high level of his own observatory, at the low level of the Kashmir Valley and in New Zealand, whither he went to select a site for a solar observatory. He also refers to the experience of W. H. Pickering, in Jamaica, and of Major Molesworth, in Ceylon. His conclusion is that a high elevation is generally admirable for night observations but poor for solar work. At Mt. Wilson and Kodaikanal the solar observations are usually made just after sunrise, when the night conditions of the atmosphere still persist, but during much of the day the seeing is poor. Mr. Evershed has found the Kashmir Valley excellent for the sun, and he expresses the view that an island site far from continental land areas would have good definition both by day and by night.

It will be interesting to watch the results of observations at the new observatory near Victoria, B.C., where the great 6-foot reflector is located the mirror for which, though not yet in place, is expected at any time. The site is 700 feet above the sea and on an island, though not very far from the mainland.

C. A. C.

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